

*Life* **BEYOND**  
*the* **ILLUSION**  
*of* **PRESENT**

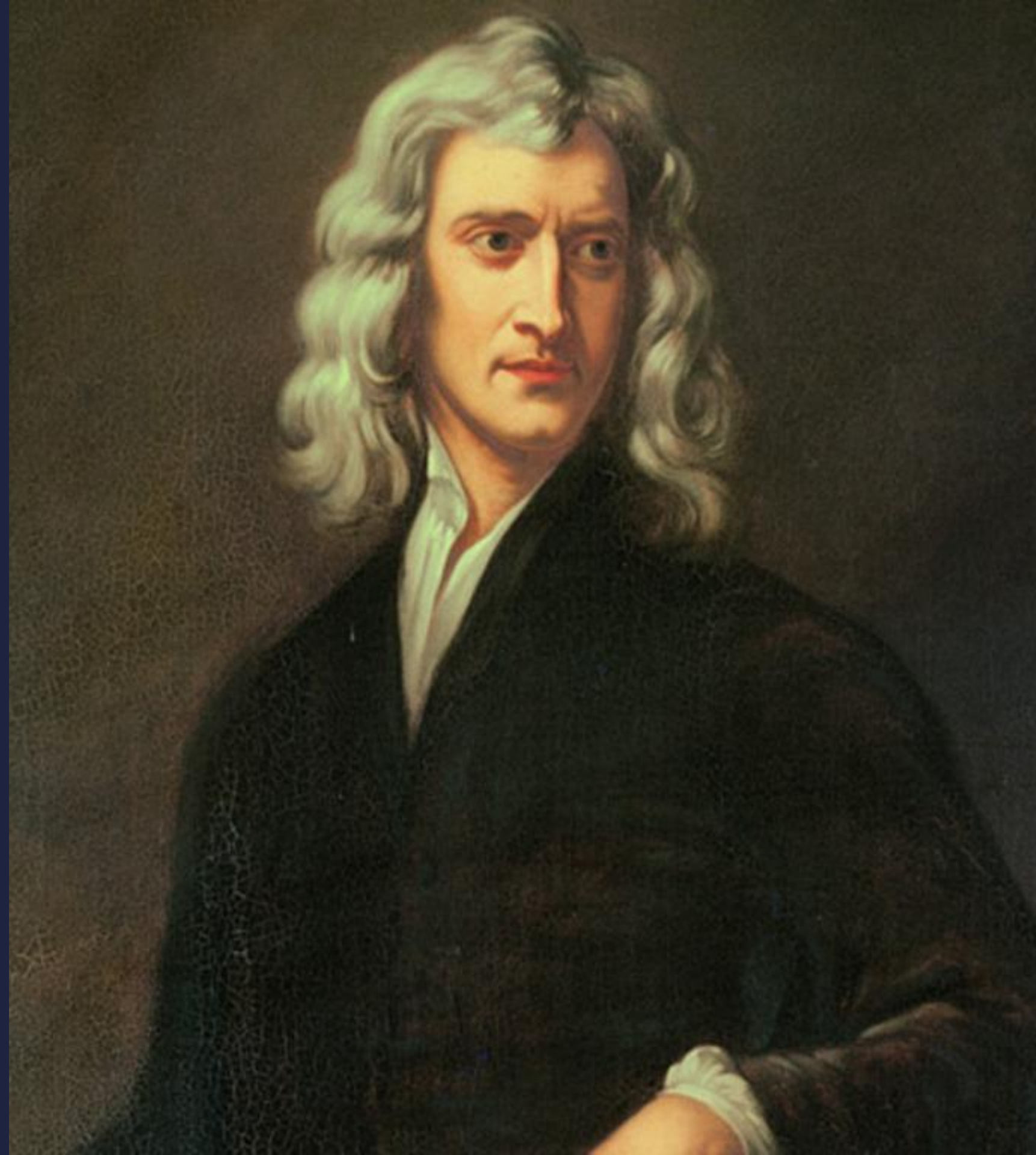
Jonas Bonér  
**CTO Typesafe**  
**@jboner**

**"Time is a device that was invented to keep everything  
from happening at once."**

**- Graffiti on a wall at Cambridge University**

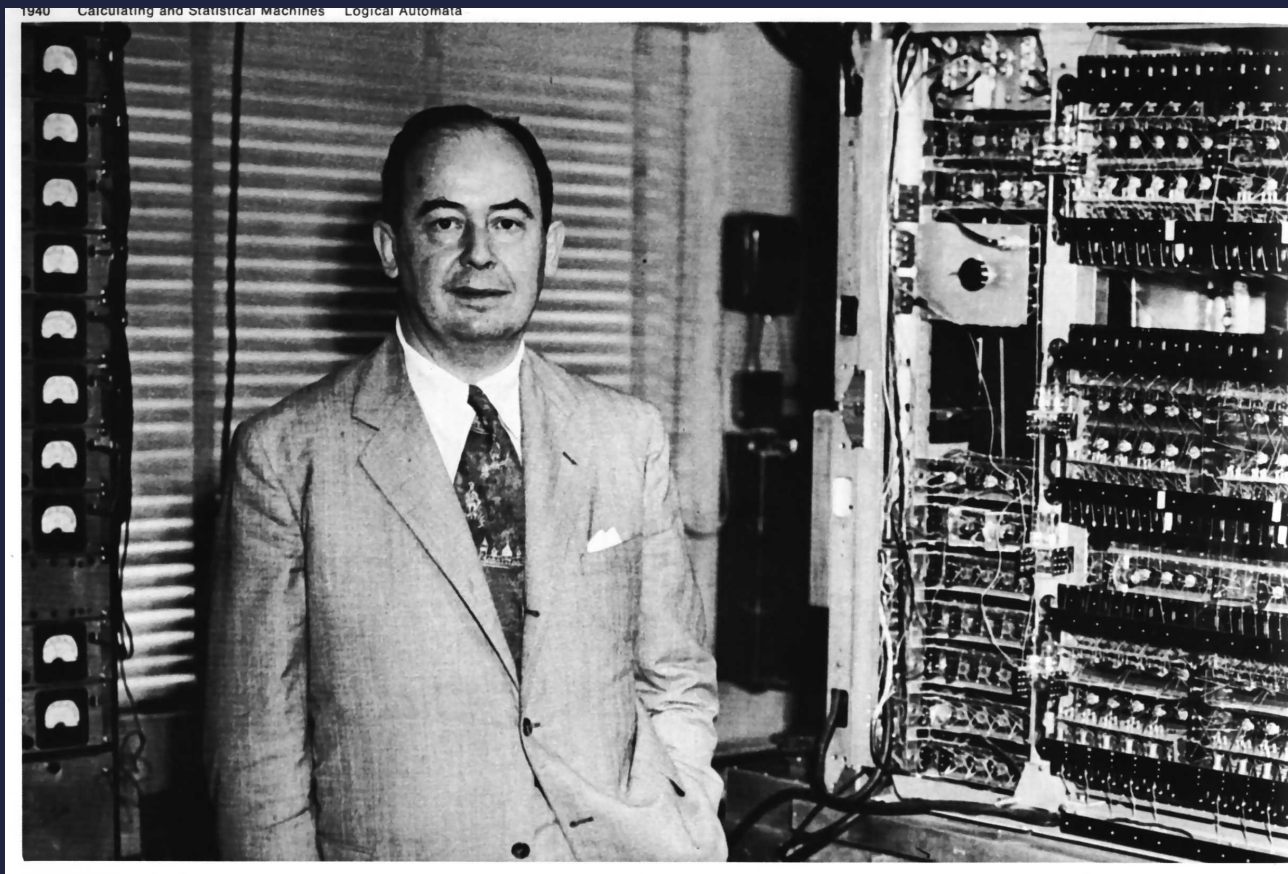


*Newton's*  
**PHYSICS**



**THIS SIMPLIFIED MODEL IS  
VERY APPEALING TO US**

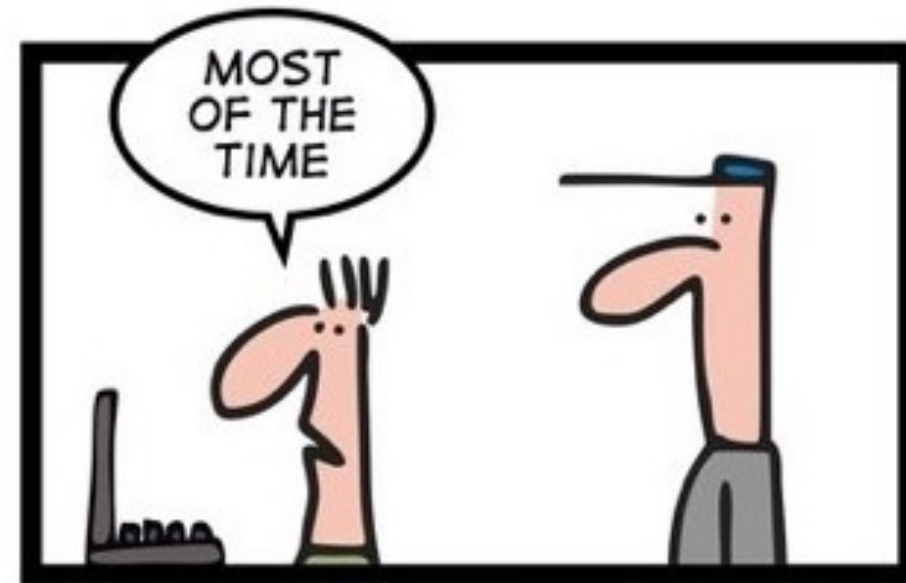
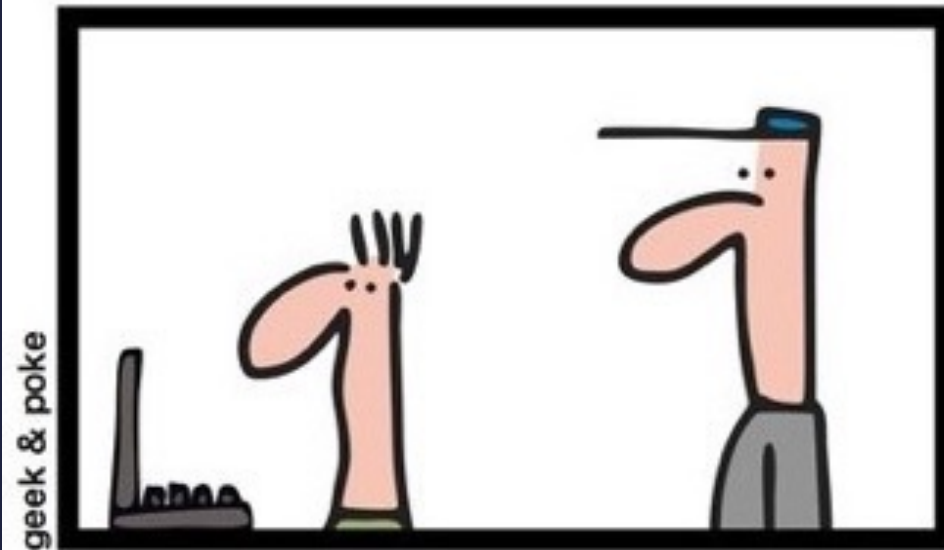
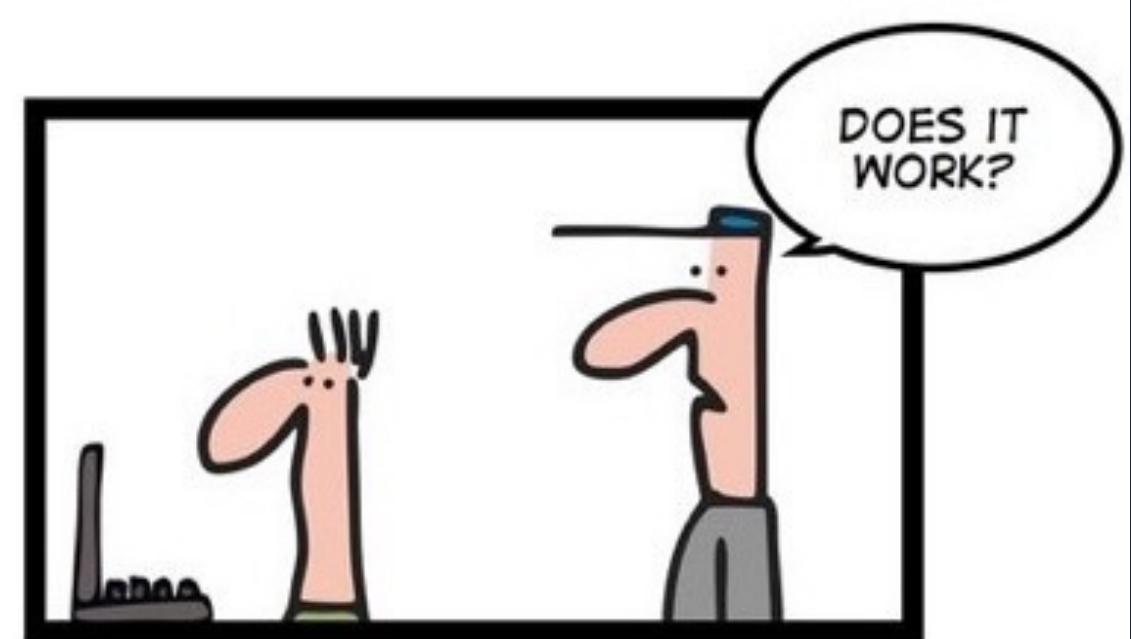
# *von Neumann* **ARCHITECTURE**





**BACK THEN, LIFE WAS GOOD**

**THEN, ALONG CAME  
CONCURRENCY  
MADE LIFE MISERABLE**





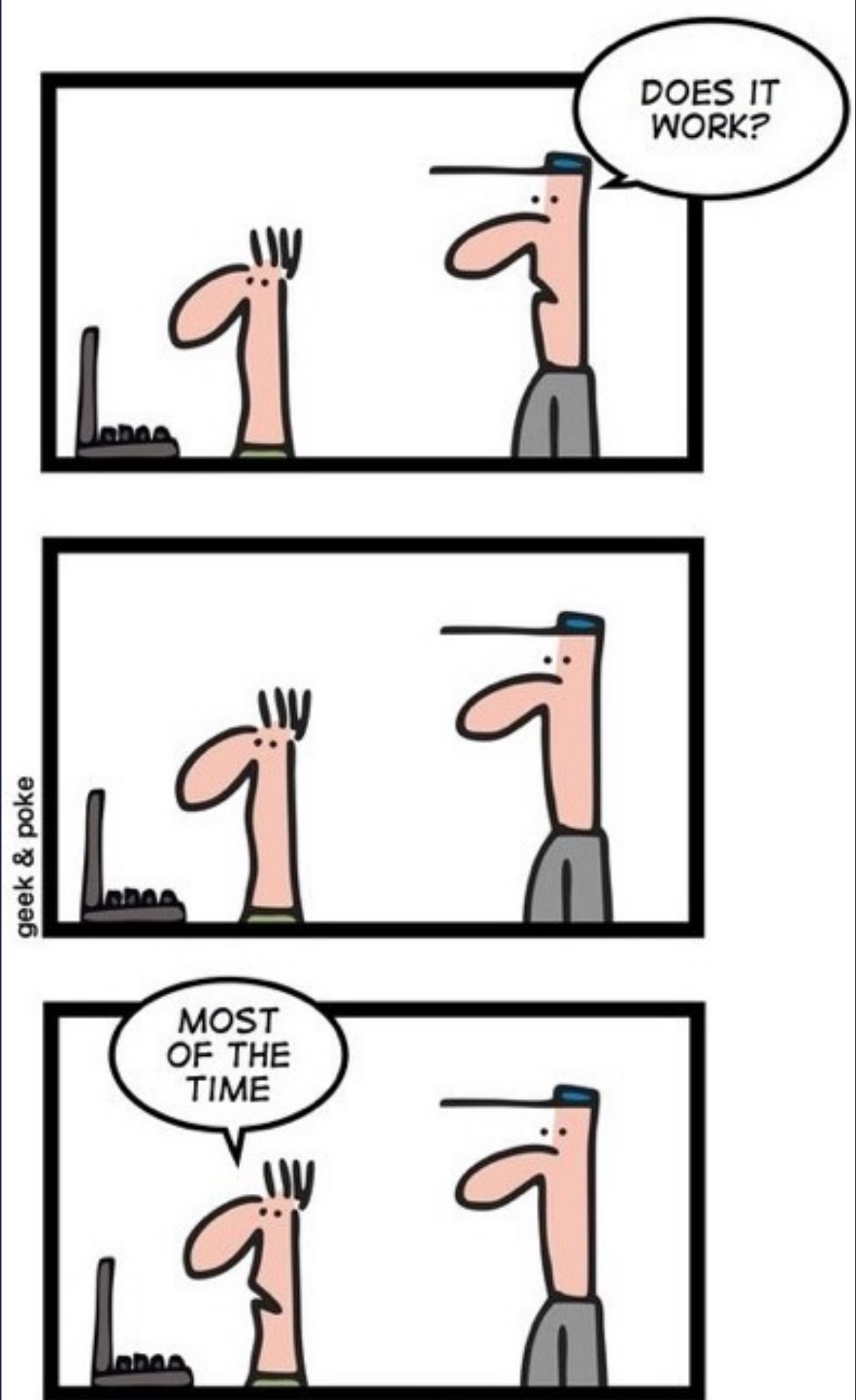
*Jim Gray's*  
**TRANSACTIONS**  
**SAVE THE DAY**



*Jim Gray's*  
**TRANSACTIONS**  
**SAVE THE DAY**

So, can we *go home* now?

**WELL, ALONG CAME**  
**DISTRIBUTION**  
**MADE LIFE MISERABLE, *again...***

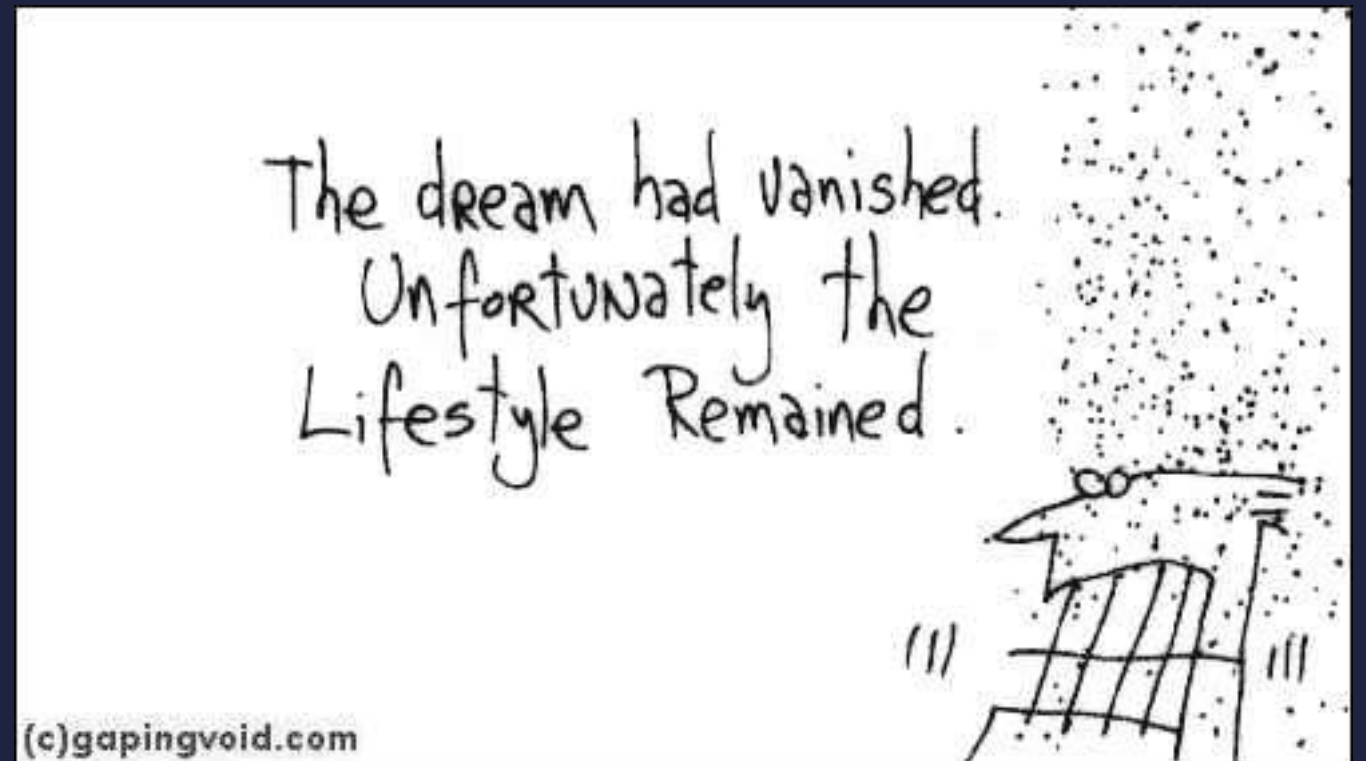


*But don't be surprised*

**UNFORTUNATELY,**

**THIS IS NOT**

**HOW THE WORLD WORKS**



$$c = (T \cdot 8 \cdot \log \frac{1}{2} + 3\alpha + 6 \ln 11)^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \alpha dx + \frac{3[(3+7x)^2 + 6 + 3T]}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \frac{(3+7x)^2 + 6 + 3T}{(5+y)(8+z)+1} dx + \frac{3[(3+7)^2 + 6 + 3T]}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \frac{(3+7x)^2 + (\beta - 180^\circ) + 3T}{(5+y)(8+z)+1} dx + \frac{3[(3+7)^2 + (\beta - 180^\circ) + 3T]}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \frac{\sqrt{3+7x + (\beta - 180^\circ) + 3T}}{(5+y)(8+z) + \log 8} dx + \frac{3\sqrt{3+7x + (\beta - 180^\circ) + 3T}}{(5+y)(8+z) + \log 8} + 6 \ln 11 \right]^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \alpha dx + \frac{3\sqrt{3+7x + (\beta - 180^\circ) + 3T}}{(5+y)(8+z) + \log 8} + 6 \ln 11 \right]^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \alpha dx + \frac{3\sqrt{3+7x + (\beta - 180^\circ) + 3T}}{(5+y)(8+z) + \log 8} + 6 \ln 11 \right]^2$$

$$c = \left[ \int_{x_1}^{x_2} \sum_{i=1}^{\infty} \alpha dx + \frac{3\sqrt{3+7x + (\beta - 180^\circ) + 3T}}{(5+y)(8+z) + \log 8} + 6 \ln 11 \right]^2$$

"The future is a function of the past."  
 - A. P. Robertson



**"The (local) present is a merge function of  
multiple concurrent pasts."**

**– Me**

```
val newLocalPresent = observedPasts.  
  foldLeft(oldLocalPresent) { _ merge _ }
```



**WE NEED TO** EXPLICITLY MODEL **THE**  
**LOCAL PRESENT AS**  
FACTS DERIVED **FROM THE**  
MERCING **OF MULTIPLE**  
CONCURRENT PASTS

**INFORMATION IS ALWAYS FROM THE PAST**



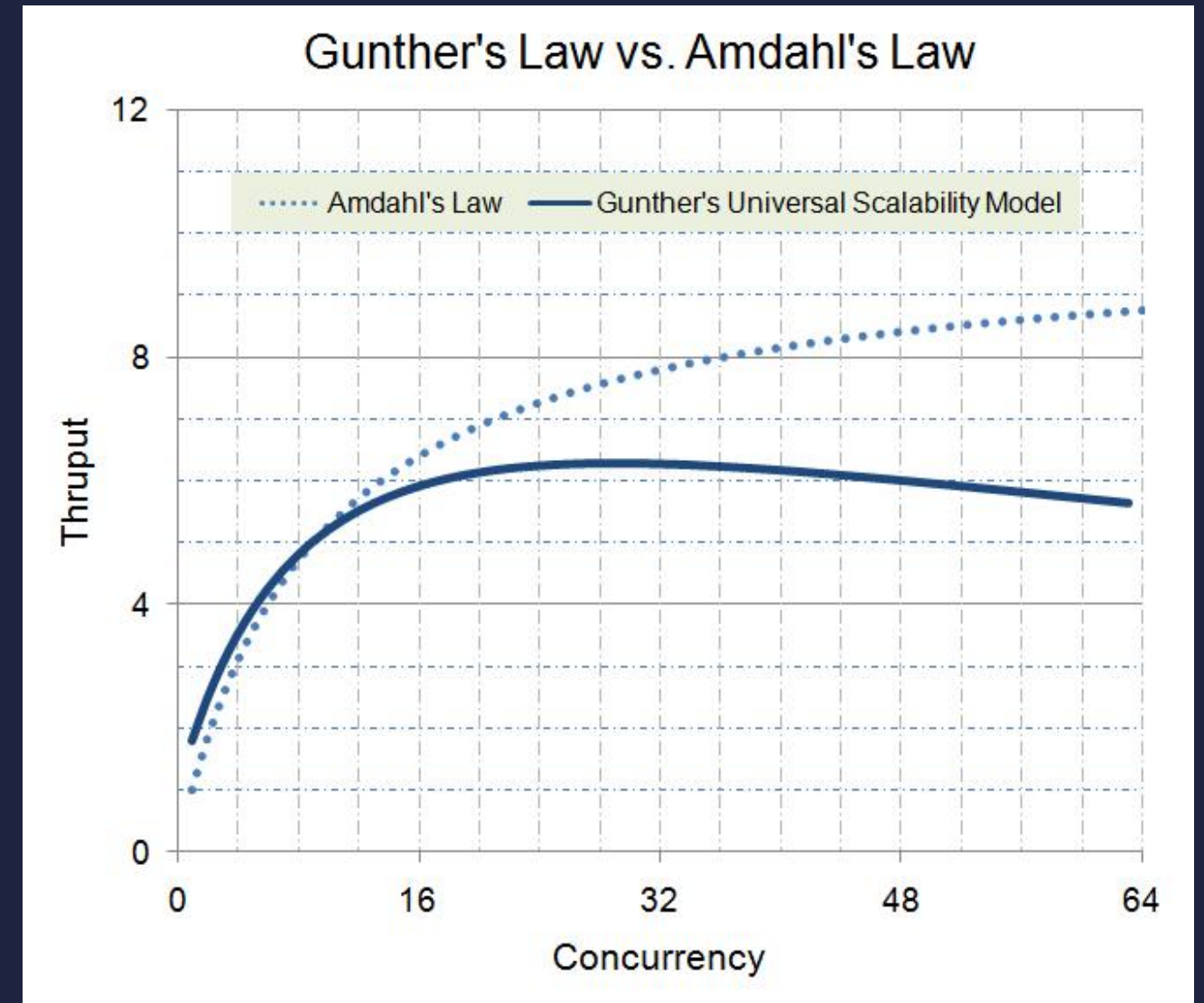
**THE TRUTH  
IS CLOSER TO  
EINSTEIN'S  
PHYSICS**





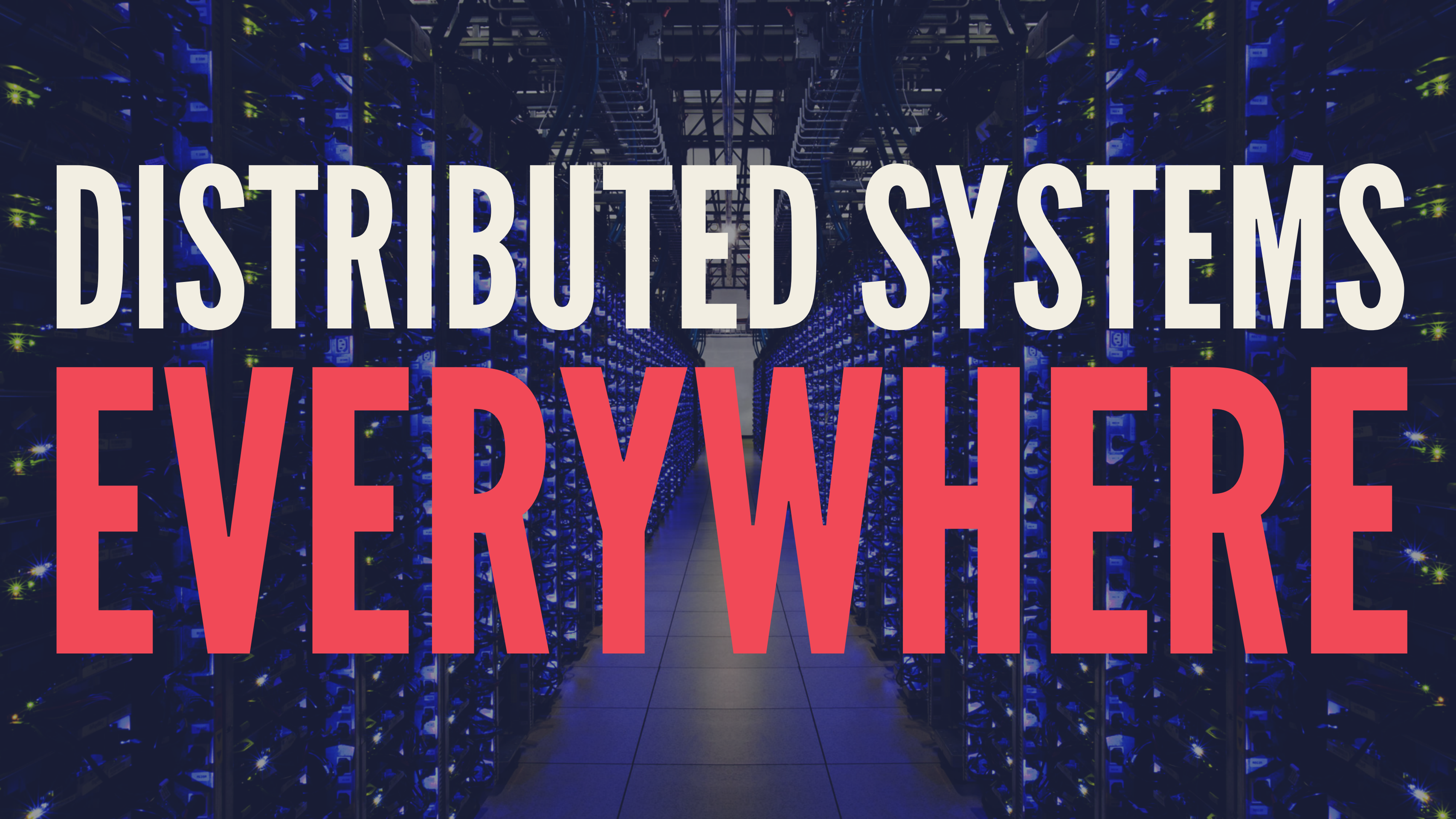
INFORMATION HAS  
**LATENCY**

THE COST OF MAINTAINING  
THIS ILLUSION IS INCREASED  
**CONTENTION &  
COHERENCY**





**AS LATENCY GETS HIGHER, THE  
ILLUSION CRACKS EVEN MORE**


A perspective view of a server room with rows of server racks on both sides, receding into the distance. The racks are filled with equipment, and numerous small blue lights are visible, creating a sense of depth and activity. The floor is a light-colored tile.

**DISTRIBUTED SYSTEMS**

**EVERYWHERE**

A man with a mustache and sunglasses, wearing a light-colored suit and tie, is smiling and giving a thumbs up with both hands. He is standing outdoors in front of a large, spiny cactus. The background shows a clear blue sky and some greenery.

**THE NETWORK IS RELIABLE...NAT**



**"If a tree falls in a forest and no one is around to hear it, does it make a sound?"**

**— Charles Riborg Mann**

*Information* **CAN** (and will) **GET LOST**



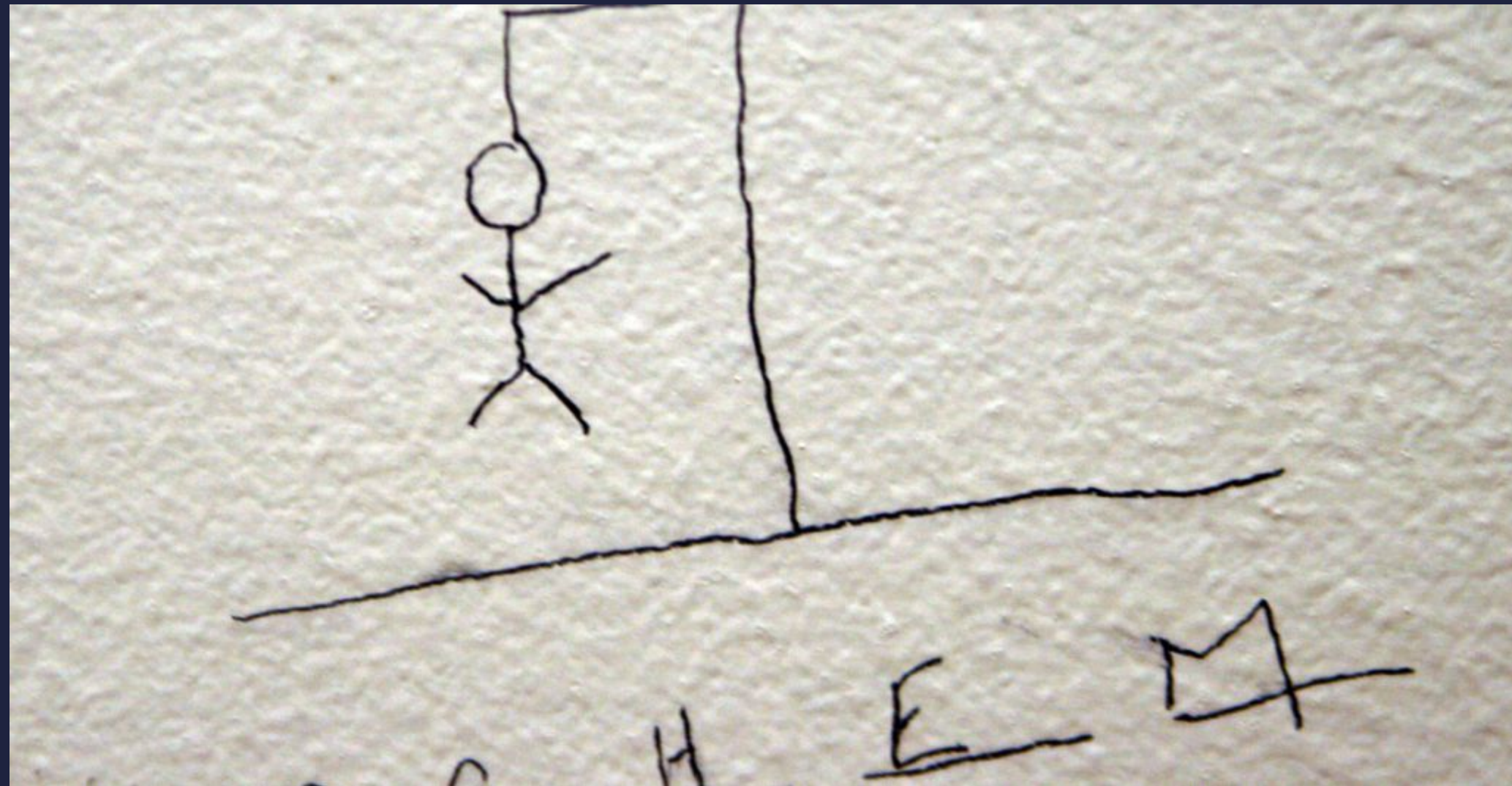
HOW DO WE DEAL WITH  
INFORMATION LOSS  
IN REAL LIFE?

**WE USE A SIMPLE PROTOCOL OF**

*Confirm, Wait & Repeat*



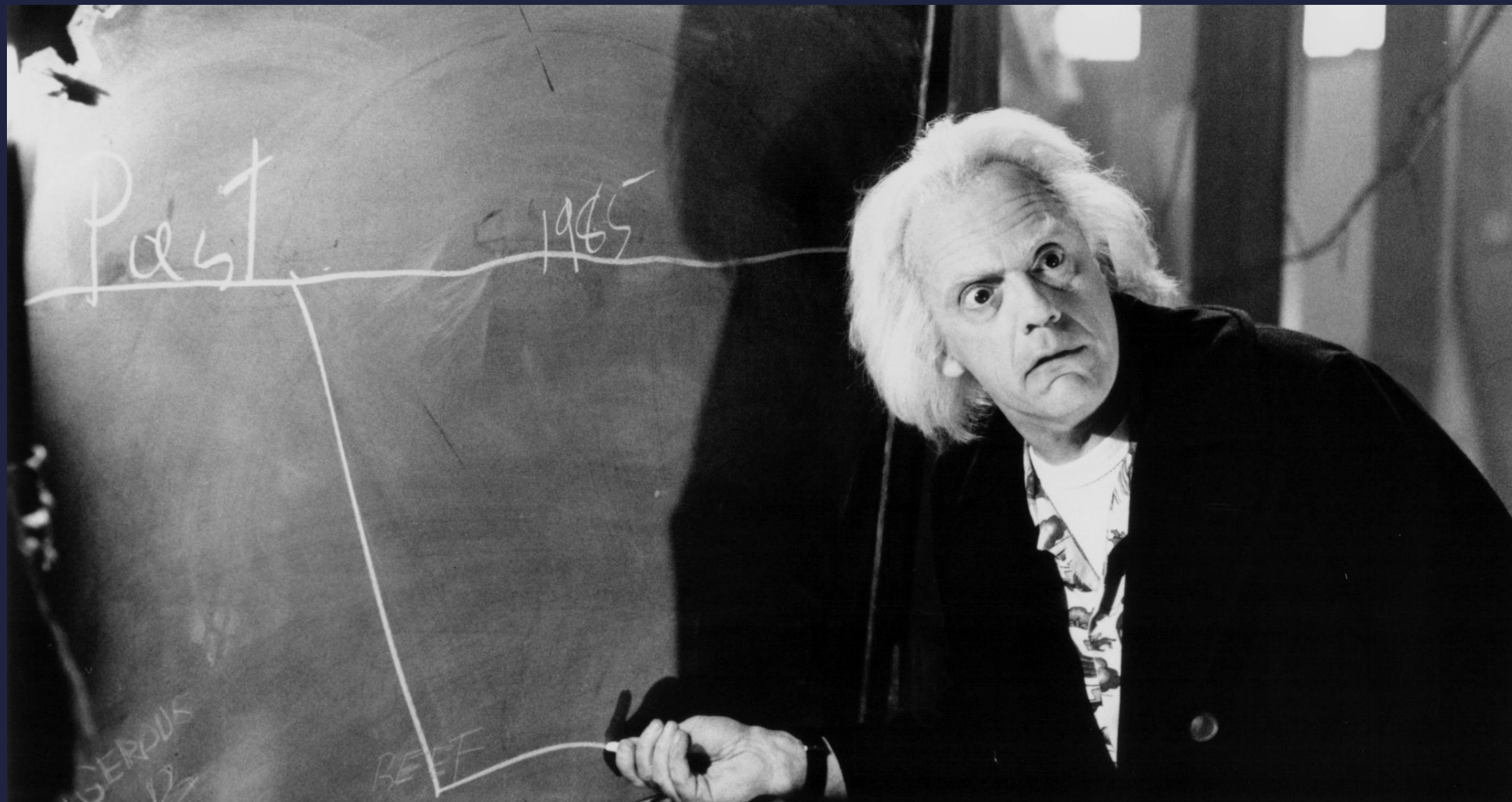
We fill in **THE BLANKS**



...AND IF WE ARE WRONG, WE TAKE  
**COMPENSATING ACTION**

**APOLOGY-ORIENTED PROGRAMMING - PAT HELLAND (IN MEMORIES, GUESSES, AND APOLOGIES)**

# Can we **REWRITE THE PAST?**



*The bottom line:*

**WE CAN'T FORCE THE WORLD INTO A**

**SINGLE GLOBALLY CONSISTENT**

**PRESENT**

Should we just **GIVE UP?**





**I BELIEVE THAT THERE IS A  
PATH FORWARD**

WE NEED TO TREAT  
TIME AS A  
FIRST CLASS CONSTRUCT

WHAT IS TIME, *really?*

**TIME IS THE  
SUCCESSION OF  
CAUSALLY RELATED EVENTS**



*How can we*

**MANAGE**

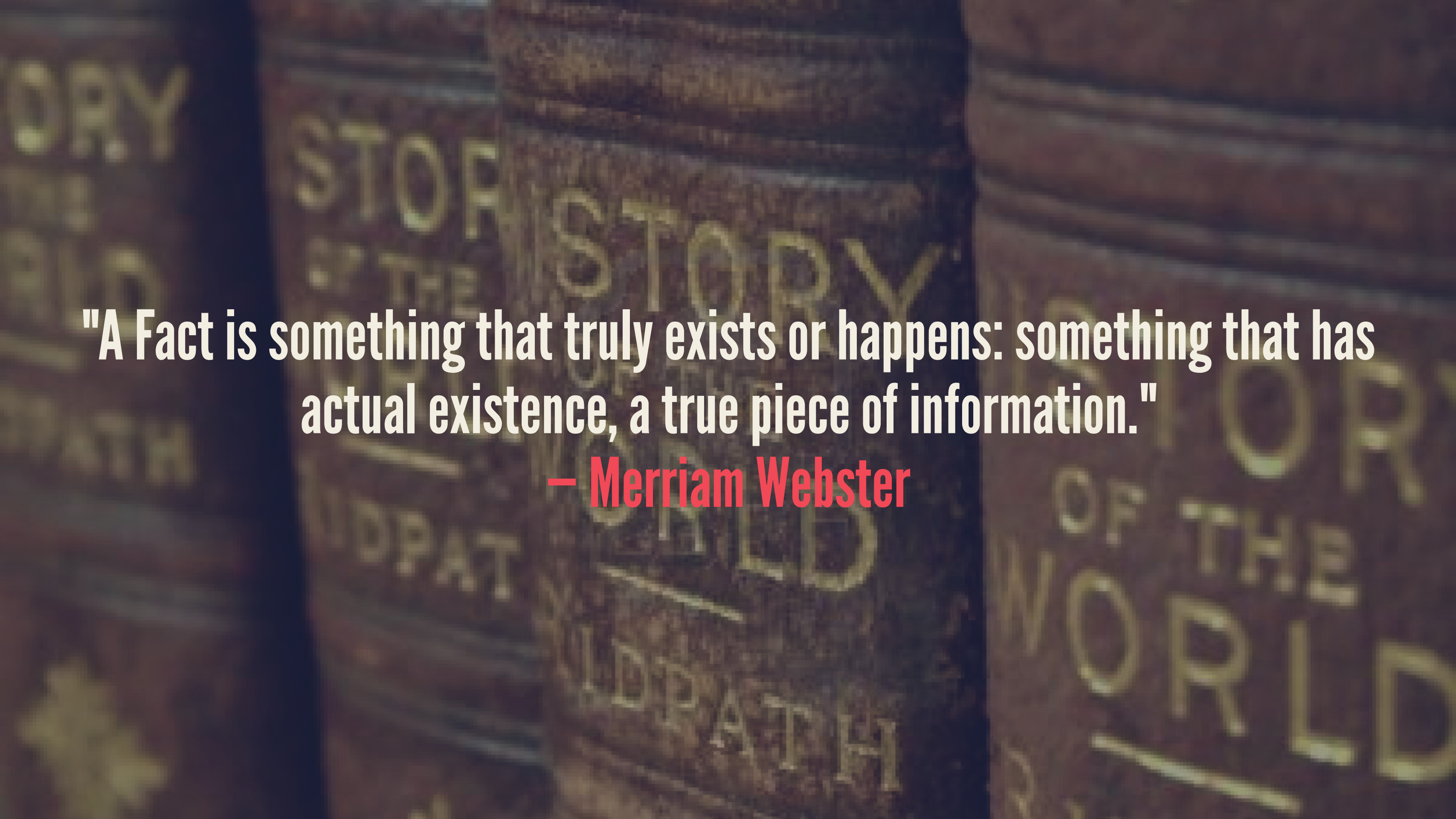
**TIME?**



*Think in* **FACTS**

*What is a*

**FACT?**



**"A Fact is something that truly exists or happens: something that has actual existence, a true piece of information."**

**– Merriam Webster**

**IMMUTABILITY**

*is a requirement*

*So, do variables*

**HAVE A PURPOSE IN LIFE?**

"The **assignment statement** is the von Neumann bottleneck of programming languages and **keeps us thinking in word-at-a-time** terms in much the same way the computer's bottleneck does."

– **John Backus (Turing Award lecture 1977)**

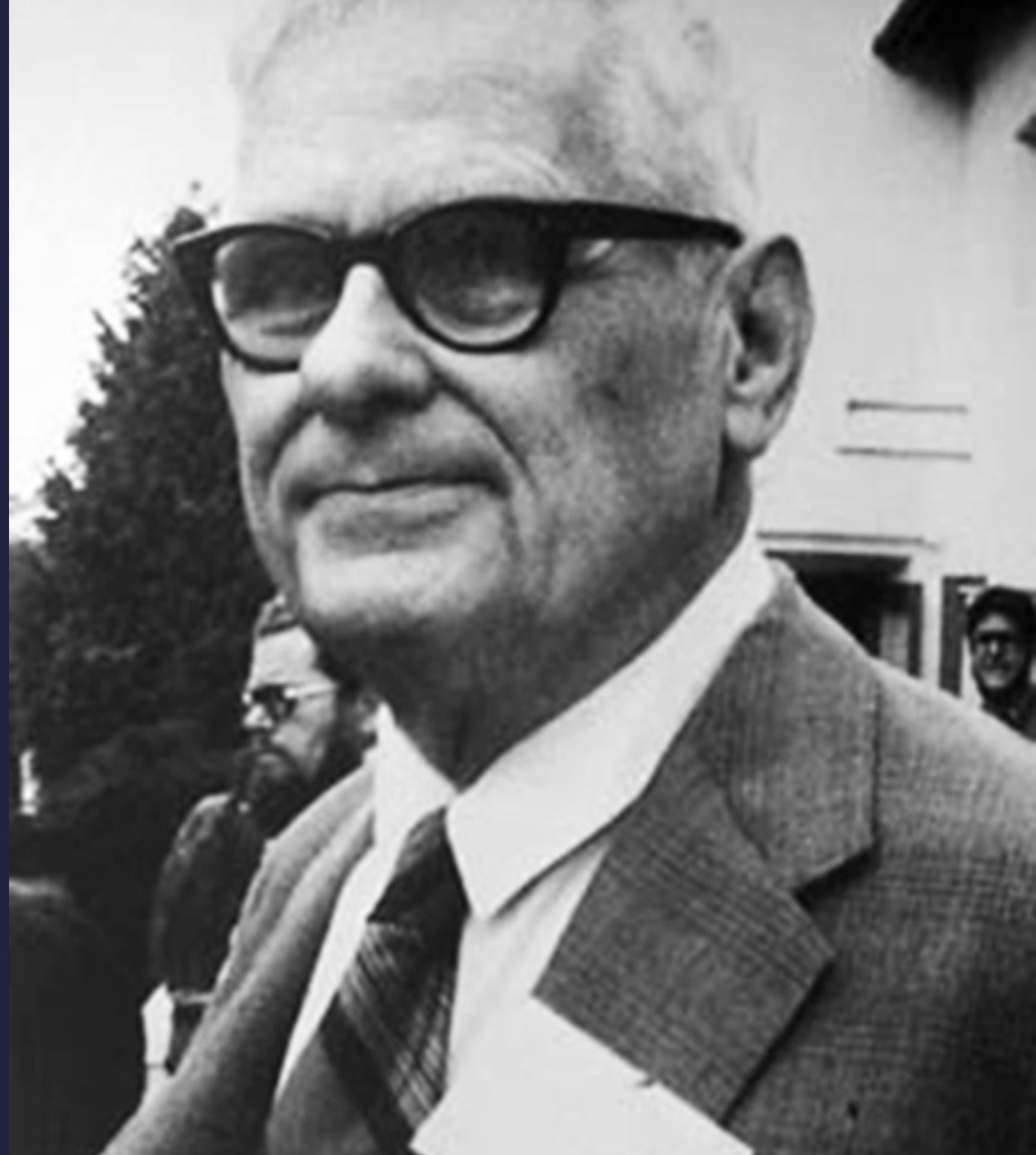
**MUTABLE STATE  
NEEDS TO BE  
CONTAINED**



*Ok, but how should we*

**MANAGE FACTS?**

*Functional*  
**PROGRAMMING**



*Logic*

**PROGRAMMING**



*Dataflow*

**GRAPHS**





**NEVER  
DELETE  
FACTS**

**"When bookkeeping was done with clay tablets or paper and ink, accountants developed some clear rules about good accounting practices. One never alters the books; if an error is made, it is annotated and a new compensating entry is made in the books. The books are thus a complete history of the transactions of the business. Update-in-place strikes many systems designers as a cardinal sin: it violates traditional accounting practices that have been observed for hundreds of years."**

**— Jim Gray (1981)**

CR

UD

**"Database is a cache of a subset of the log."**  
**– Pat Helland (2007)**



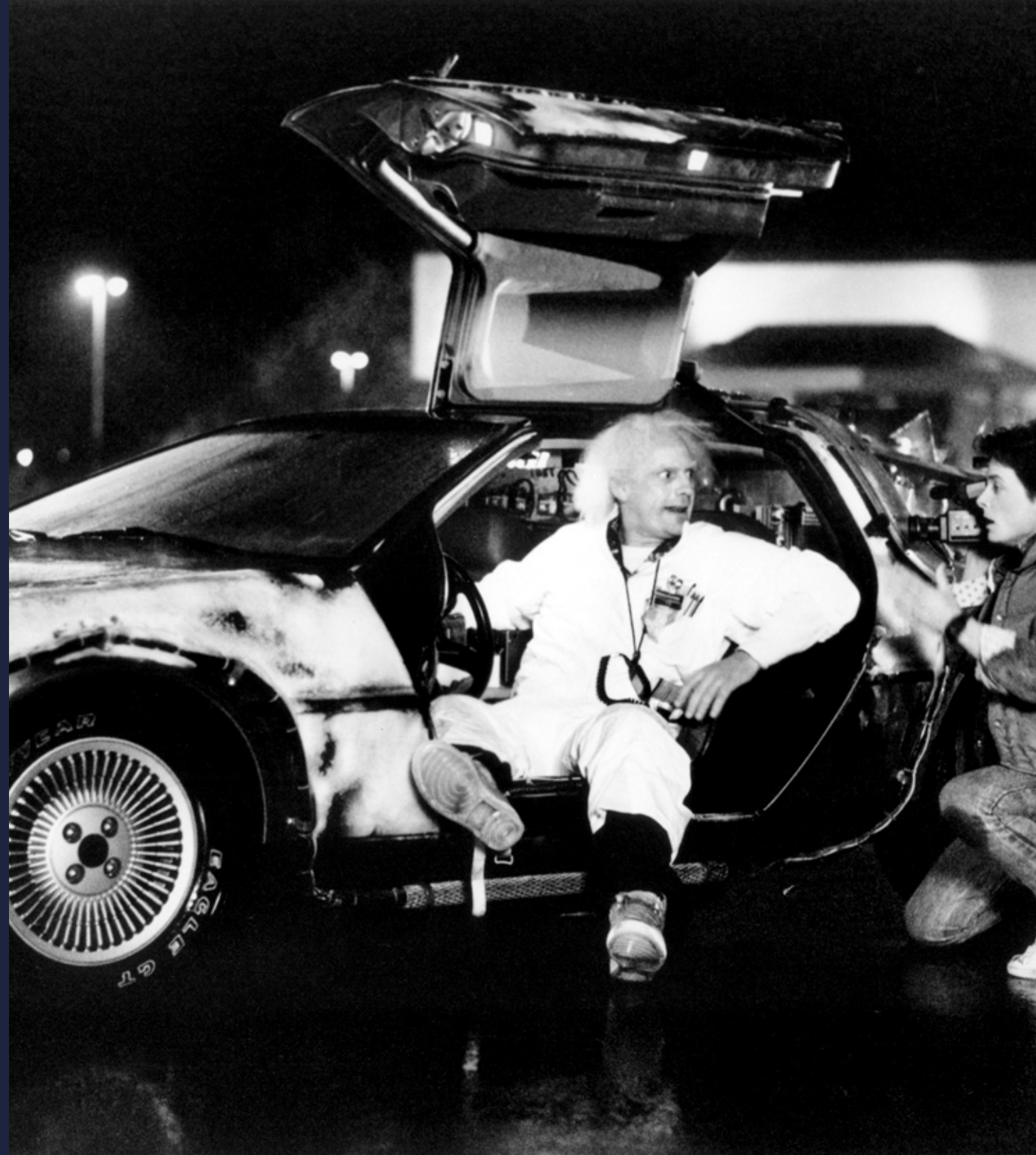
*Store facts in an*

**EVENT LOG**

*The log allows*

**TIME**

**TRAVEL**



Allows us to *shift* our focus from

**DATA AT REST**, *to*

**DATA IN MOTION**

# Stream Processing



CONSTRUCTING A SUFFICIENTLY CONSISTENT

LOCAL PRESENT

MEANS EMPLOYING

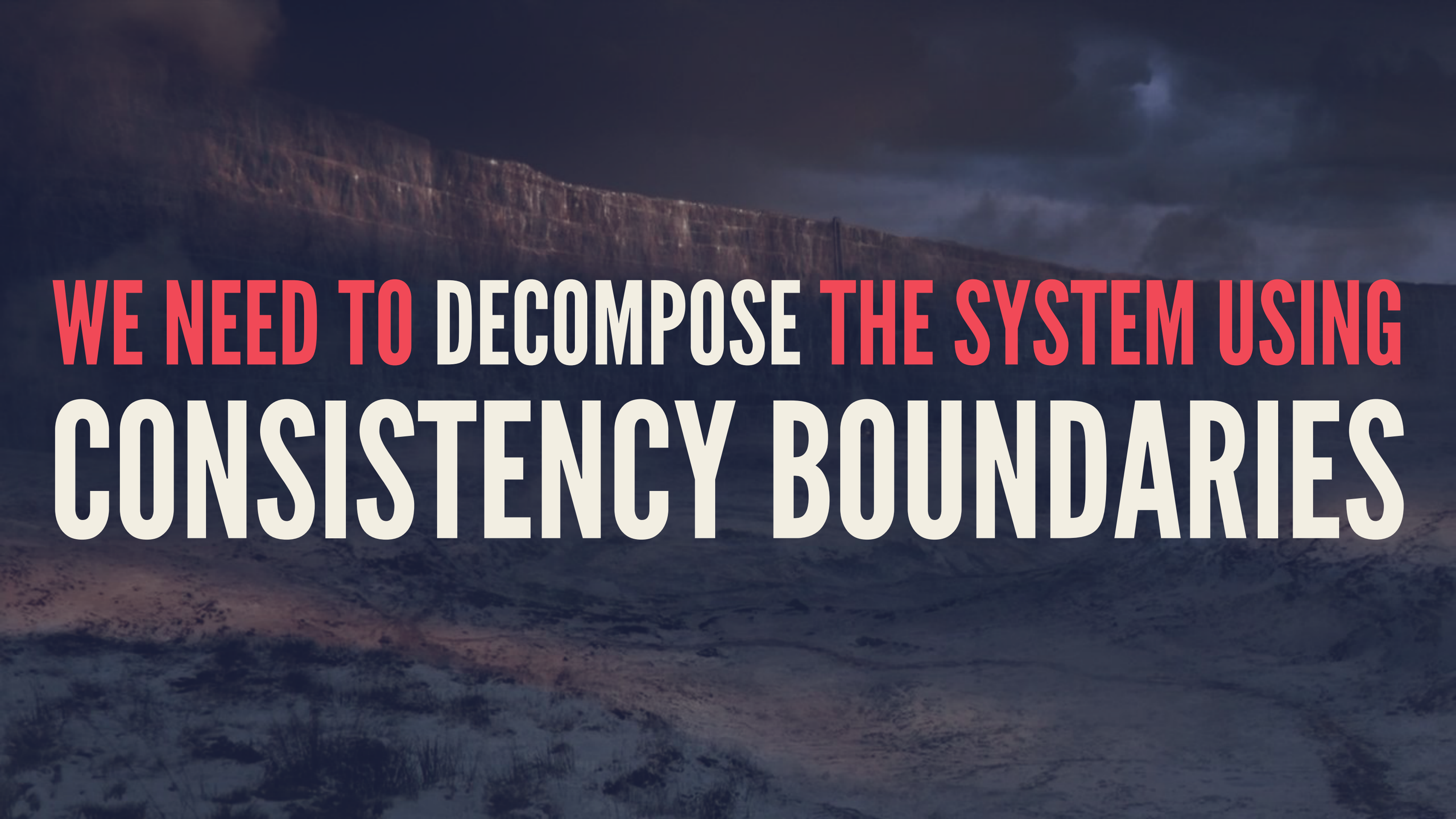
CONSISTENCY MECHANISMS

# Consistency

**WHAT?**

**WHY?**

**WHEN?**



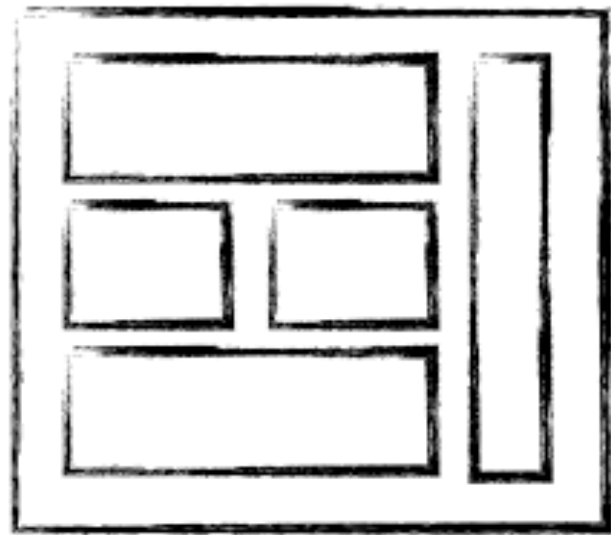
**WE NEED TO DECOMPOSE THE SYSTEM USING  
CONSISTENCY BOUNDARIES**



**INSIDE DATA: OUR CURRENT PRESENT**  
**OUTSIDE DATA: BLAST FROM THE PAST**  
**BETWEEN SERVICES: HOPE FOR THE FUTURE**

— **PAT HELLAND** (DATA ON THE INSIDE VS DATA ON THE OUTSIDE)

# MicroSERVICE



MONOLITHIC/LAYERED



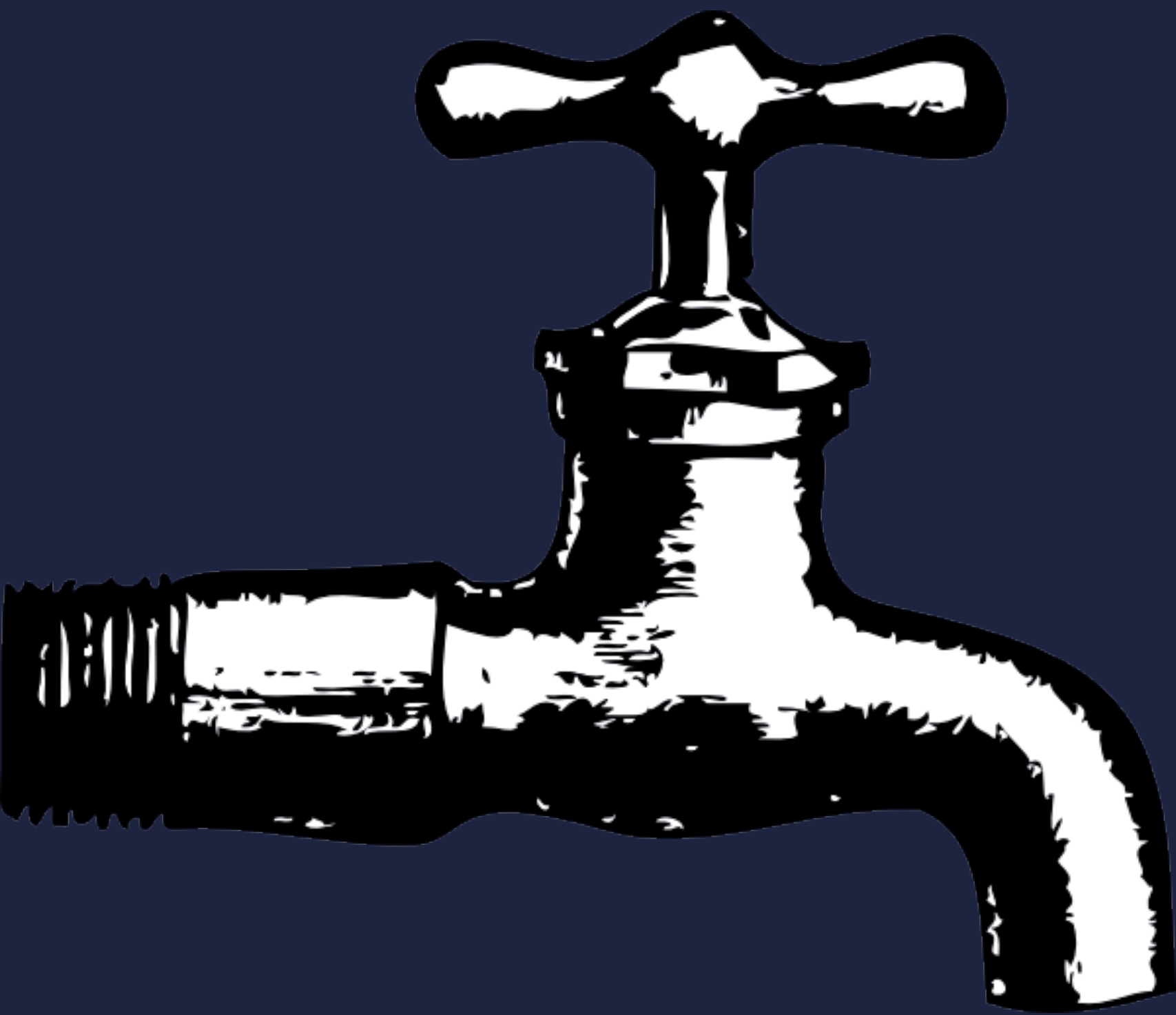
MICRO SERVICES

# AGGREGATE *Root*





# **WITHIN** THE CONSISTENCY BOUNDARY



**EVENT**

*Sourcing*



**BETWEEN THE**

*Consistency*

*Boundaries*

**IT'S A ZOO**

*Decoupling in*

**TIME / SPACE**



**STRONG**

**CONSISTENCY**

*The wrong default*



*Here, we are living in the*  
**LOOMING SHADOW OF**  
**IMPOSSIBILITY**  
**THEOREMS**



**FLP**

**CONSENSUS IS IMPOSSIBLE**

# PROTOCOLS CLIMB THE LADDER OF KNOWLEDGE

$C\phi$ : Common Knowledge (infinite number of  $i$ )

$E_i\phi$ : (Everyone knows  $* i$ )  $\phi$

$E_3\phi$ : (Everyone knows  $* 3$ )  $\phi$

$E_2\phi$ : Everyone knows Everyone knows  $\phi$

$E_1\phi$ : Everyone knows  $\phi$

$S\phi$ : Someone knows  $\phi$

**COMMON KNOWLEDGE**  
**IS NOT ATTAINABLE VIA PROTOCOL**

**- JOSEPH HALPERN**

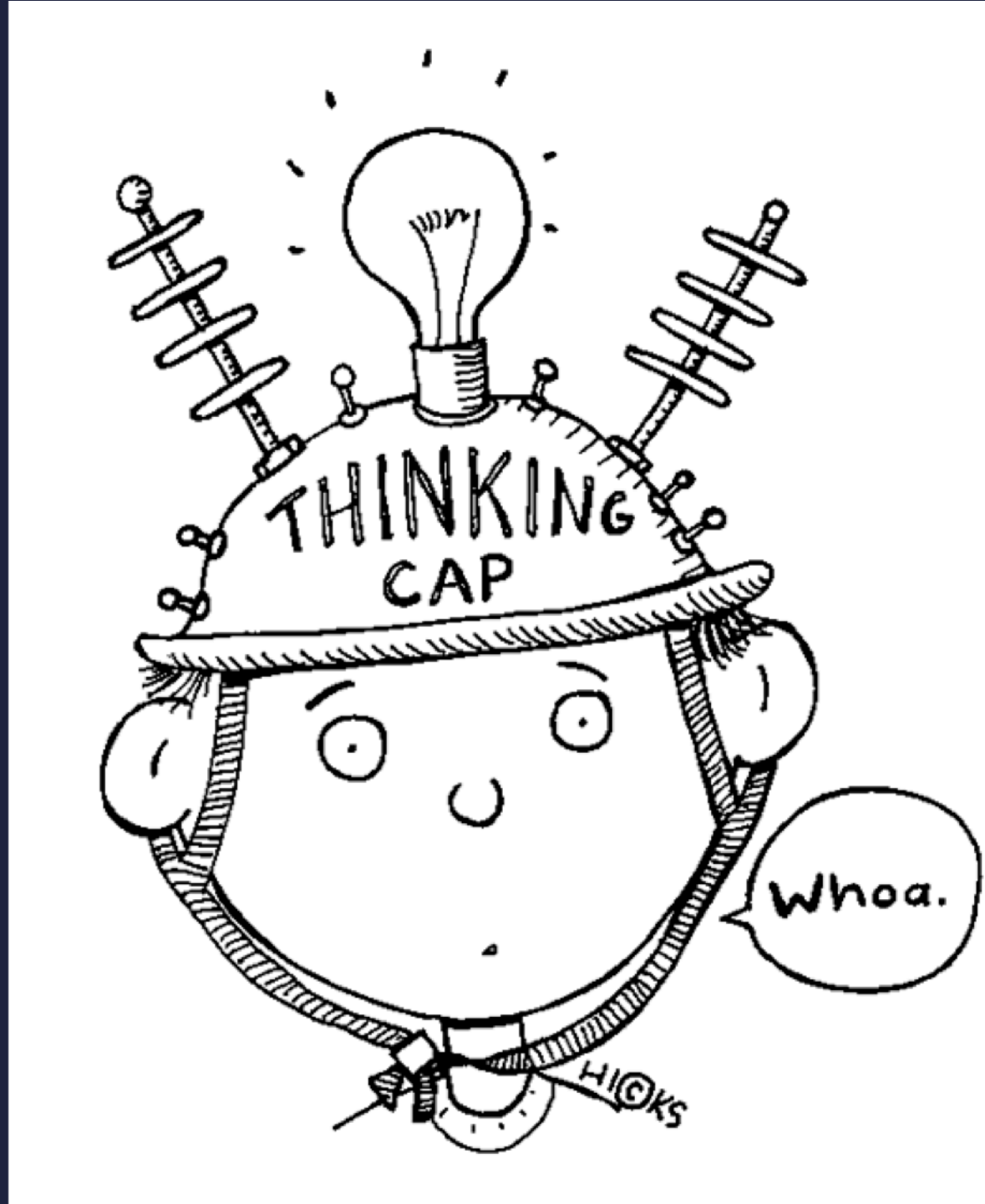


**GAP**

**CONSISTENCY IS IMPOSSIBLE**

**"Psychotics are consistently inconsistent. The essence of sanity is to be  
inconsistently inconsistent."**

**– Larry Wall**



*Dissecting*

**CAP**

**"The first principle of successful scalability is to batter the consistency mechanisms down to a minimum."**

**– James Hamilton**

# EVENTUAL CONSISTENCY

*What does it really mean?*

*Tracking* **TIME** *is tracking* **CAUSALITY**

**RELYING ON  
TIMESTAMPS  
IS A BAD IDEA**



*Instead, rely on*

**LOGICAL TIME**

*Lamport*

**CLOCKS**

**GLOBAL CAUSAL ORDERING BETWEEN**

# *Vector* **CLOCKS**

**PARTIAL CAUSAL ORDERING BETWEEN EVENTS**

*Causal*

**CONSISTENCY**

# What

## CONSISTENCY

## DO YOU REALLY NEED AND

# when?



# ACID 2.0

ASSOCIATIVE  
COMMUTATIVE  
IDEMPOTENT  
DISTRIBUTED



**CONFLICT-FREE REPLICATED DATA TYPES**

# DISORDERLY PROGRAMMING

## CALM THEOREM



KEEP  
CALM  
AND  
CARRY  
ON

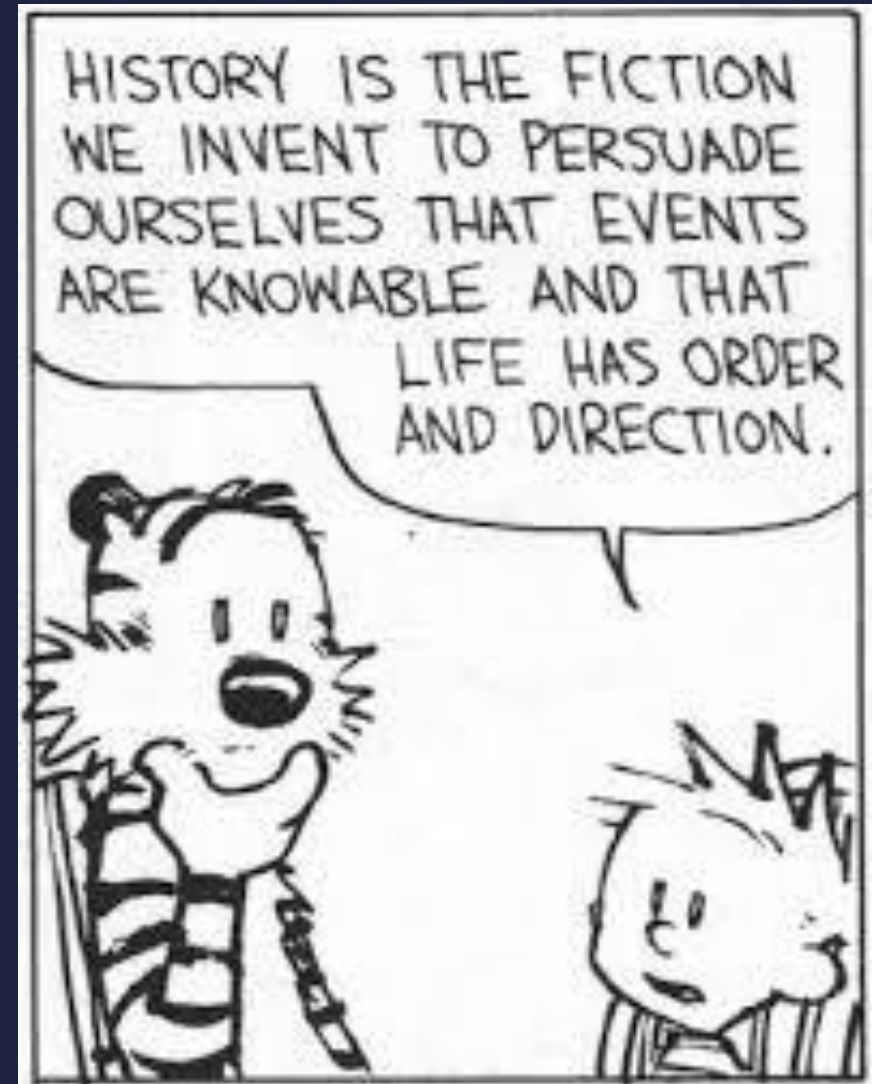


**WE ARE JUST GETTING STARTED**

A long, straight asphalt road stretches from the bottom center towards the horizon, flanked by dry, brown grass. The sky is a deep, dark blue, suggesting a clear but cool day. The overall mood is one of vastness and forward-looking perspective.

**WE HAVE A LONG ROAD AHEAD OF US...**

Thanks  
FOR LISTENING



*Life* **BEYOND**  
*the* **ILLUSION**  
*of* **PRESENT**

Jonas Bonér  
**CTO Typesafe**  
**@jboner**